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SHORT COMMUNICATION

The South African scorpion *Pseudolychas ochraceus* (Hirst, 1911) (Scorpiones: Buthidae) can reproduce by parthenogenesis

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Abstract. Of all scorpion species described to date, only a small fraction are known to reproduce without fertilization by a male, instead producing offspring by parthenogenesis. Here we show that isolated females of the buthid *Pseudolychas ochraceus* (Hirst, 1911) are capable of parthenogenetic reproduction and we provide data on the postembryonic growth of this species.

Keywords: Arachnida, scorpions, asexual reproduction, postembryonic and embryonic development

Sexual reproduction is the predominant reproductive strategy in multicellular eukaryotes and as such the vast majority of animal species develop from a zygote produced by the fusion of a female and a male gamete (Williams 1975). Parthenogenesis, the development of offspring from unfertilized eggs, occurs in diverse invertebrate and vertebrate taxa, albeit at a low frequency (White 1978). With the exception of mites in which various types of parthenogenetic reproduction are known to occur and parthenogenesis is prevalent in certain families (Oliver 1971; Sabelis 1985), asexual reproduction is quite rare in other arachnid orders (Bell 1982). Parthenogenesis is known to occur in several species of spiders (Edwards et al. 2003), harvestmen (Tsurusaki 1986), amblypygids (Armas 2000; Weygoldt 2005, 2007; Seiter & Wolff 2014) and scorpions (review in Francke 2008; Lourenço 2008), and is strongly suspected to occur in some species of pseudoscorpions (Dashdamirov & Golovatch 2005), schizomids (Nedvěd et al. 2011; Zawierucha et al. 2013) and palpigrades (Christian & Christophoryová 2013) based on the observation of all-female populations or a pronounced scarcity of males. Although the majority of claims about parthenogenetic reproduction in scorpion species were proven by experimental evidence, some are based on field observations or uneven sex distributions in samples of collected species alone (Francke 2008; Lourenço 2008). During a revision of the scorpion genus *Pseudolychas* Kraepelin, 1911, Prendini (2004) observed only five males in 115 preserved specimens of *Pseudolychas ochraceus* (Hirst, 1911) and suggested that this species might be capable of asexual reproduction. By rearing captive-born female specimens under isolation until maturation and observing that these gave birth to an all-female brood without being inseminated, we show that females of *P. ochraceus* from a population located in the vicinity of Onderstepoort, Pretoria, Gauteng Province in South Africa are capable of parthenogenetic reproduction.

All specimens were collected near Onderstepoort, Pretoria, Gauteng Province in South Africa and were found under stones, bark and leaf litter in humid microhabitats. Captive-born specimens were kept in isolation as soon as they left their mother's back after reaching the second instar. Specimens were kept in plastic terraria of different sizes using standard methods. The enclosures contained a 1 cm deep layer of soil-sand mixture and pieces of bark for the specimens to hide among. Food consisted of nymphs of *Acheta domesticus* (Linnaeus, 1758). All specimens were reared under the same conditions (29 ± 1°C, 35 ± 5% relative humidity and 16:8 h L:D photoperiod) and fed in intervals of seven days. Dead specimens were stored in ethanol (70% solution) and deposited in the Natural History Museum Vienna, Austria (NHMW 27605). Specimens were studied, measured, and photographed with a stereomicroscope (Leica M205A) equipped with a Leica DFC420 camera. Digital images were processed using Adobe Photoshop ® 8.0 to optimize contrast features of the micrographs. The specimens were identified using the key by Prendini (2004) and the original first description by Hirst (1911). The sex was determined by the presence or absence of enlarged first pectinal teeth, a dimorphic trait observable in all postembryonic stages of this species (Fig. 1).

Our results derived from five wild-caught second instar females. They were reared in isolation in captivity. One of them reached maturity (F0) and gave birth to two female offspring (F1), which after reaching adulthood gave birth to all-female litters of 9 and 15 offspring (F2), respectively. Three F2 specimens reached adulthood, and produced three all-female litters of one, two and three offspring. One female gave birth after 217 days following final ecdysis (n = 1). The first instar specimens molted an average of 12 days after birth and consecutive moltings took place after 95 days (instar III), 135 days (instar IV), 205 days (instar V) and 248 days (instar VI, adult) of postembryonic growth (n = 2).

In a critical review, Francke (2008) proposed that the parturition of a captive isolated female collected immature in the wild is the minimal evidence required to conclude that a scorpion species is parthenogenetic. Furthermore, Francke (2008) discusses previous claims of the occurrence of parthenogenesis in scorpion species and presents arguments why establishment of parthenogenesis should not be based on parturition of immature wild-caught specimens alone. Two key arguments are a reported case of a post-parturition molt in *Tityus uruguayensis* Borelli, 1901 (Toscano-Gadea 2001) and the common occurrence of iteroparity (Polis & Sissom 1990), which could cast doubt on the establishment of parthenogenesis by the parturition of specimens that were not entirely raised under conditions of isolation. Although other post-parturition molts have never been observed in scorpions, further confirmation of such an event would have serious implications on establishing parthenogenesis based on parturition of wild caught specimens. Therefore, we follow the more stringent criteria proposed by Francke (2008) to confirm the previously suspected parthenogenesis in *P. ochraecus* (Prendini 2004): raising captive born females to maturity in isolation and showing that these can reproduce without being inseminated. Following these criteria, parthenogenesis was previously established for seven buthid and one hormurid scorpion species to

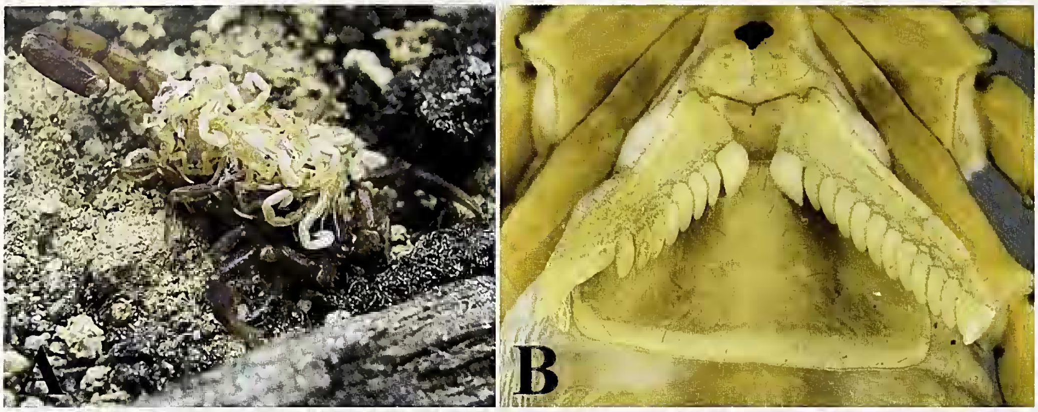

Figure 1.—*Pseudolychas ochraceus* specimen in captivity. A. Adult female with second instar offspring. B. Pectinal area with the elongated first pecten, characteristic of females. Photos by Jonas Wolff.

which we now add *P. ochraecus* as the eighth buthid scorpion of which parthenogenetic reproduction was shown by parturition of a captive-born female raised in isolation (Tab. 1) We note that the description of parthenogenesis in *Tityus stigmurus* (Thorell, 1876) by Ross (2010) leaves little room to question the ability of this species to reproduce parthenogentically, however, the females used in this study were only isolated in a subadult state.

Based on our data, we cannot say whether the *P. ochraecus* specimens collected at Onderstepoort for our study belong to an all-female population reproducing exclusively by parthenogenesis. However, Prendini (2004) points out that most of the preserved specimens available in museum collections (of which ~96 % are female) were collected in suburban habitats of the major South African cities of the Gauteng conurbation where this species is abundant. In the regions outside of the cities less influenced by human activities this species is more rarely found and in some cases was never recorded. This could indicate that sexually reproducing populations of *P. ochraceus,* in which females could be facultatively parthenogenetic, predominantly occur in sparsely sampled non-urban habitats, whereas asexual all-female populations are present in suburban habitats; a population distribution pattern which would represent a case of geographic parthenogenesis as described by Vandel (1928).

This explanation is further substantiated by the observation that parthenogenetic reproduction facilitates dispersal by human activities, as only one specimen has to be introduced to a new habitat to found a new population. Many spiders introduced to European greenhouses are parthenogenetic and populations of introduced schizomids and palpigrades apparently exclusively consist of females (Nedvěd et al. 2011; Christian & Christophoryová 2013; Zawierucha et al. 2013). A well-known example for the potential of fast and effective dispersal of a parthenogenetic scorpion is the South American buthid species *Tityus serrulatus* (Lutz & Mello, 1922), which originally occurred only in a restricted region of the Brazilian state Minas Gerais but nowadays has widely spread to cities throughout the country (Lourenço & Cloudsley-Thompson 1996). Therefore, facilitated dispersal of parthenogenetic reproducing populations is an attractive explanation of why only females of *P. ochraceus* were collected in cities situated in regions where this species does not occur naturally. It would be interesting to test whether females from presumably all-female populations can reproduce with males from sexual populations to learn whether parthenogenesis in these populations is obligate or facultative.

Table 1.—Scorpion species in which the capability to reproduce by parthenogenesis was established by fulfillment of the criterion that a captive-born female raised to adulthood in isolation gives birth. Within Buthidae, species are given in chronological order by record year.

Species	Record of parthenogenesis
Hormuridae Laurie, 1896	
Liocheles australasiae (Fabricius, 1775)	Yamazaki & Makioka (2004)
Buthidae (Koch, 1837)	
Tityus serrulatus Lutz & Mello, 1922	Matthiesen (1962)
Tityus uruguayensis Borelli, 1901	Zolessi (1985)
Tityus trivittatus Kraepelin, 1898	Toscano-Gadea (2004)
Hottentotta hottentotta (Fabricius)	Lourenço & Ythier (2007)
Hottentotta caboverdensis Lourenço & Ythier, 2006	Lourenço, Ythier & Cloudsley-Thompson (2007)
Tityus neblina Lourenço, 2008	Lourenço & Cloudsley-Thompson (2010)
Tityus confluens Borelli, 1899	Seiter (2012)
Pseudolychas ochraceus (Hirst, 1911)	This study

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LITERATURE CITED

Armas, L.F. de. 2000. Parthenogenesis in Amblypygi (Arachnida). Avicennia 12/13:133–134.

Bell, G. 1982. The Masterpiece of Nature: the Evolution and Genetics of Sexuality. University of California Press, Berkeley.

Christian, E. & J. Christophoryová. 2013. *Eukoenia florenciae* (Arachnida: Palpigradi): Lessons from a newcomer to Central Europe and the island of Tenerife. Biologia 68:1182–1188.

Dashdamirov, S. & S.I. Golovatch. 2005. *Miscellanea chernetologica* (Arachnida: Pseudoscorpiones), based on the collection of the Natural History Museum in Vienna, Part 1. Arthropoda Selecta 14:299–301.

Edwards, R.L., E.H. Edwards & A.D. Edwards. 2003. Observations of *Theotima minutissimus* (Araneae, Ochyroceratidae), a parthenogenetic spider. Journal of Arachnology 31:274–277.

Francke, O.F. 2008. A critical review of reports of parthenogenesis in scorpions (Arachnida). Revista Ibérica de Aracnología 16:93–104.

Hirst, S. 1911. Descriptions of new scorpions. Annals and Magazine of Natural History 8:462–473.

Lourenço, W.R. 2008. Parthenogenesis in scorpions: Some history – new data. Journal of Venomous Animals and Toxins including Tropical Diseases 14:19–44.

Lourenço, W.R. & J.L. Cloudsley-Thompson. 1996. Effects of human activities on the environment and the distribution of dangerous species of scorpions. Pp. 49–60. *In* Envenomings and their Treatments. (C. Bon, M. Goyffon, eds.). Editions Fondation M. Mérieux, Lyon.

Lourenço, W.R. & J.L. Cloudsley-Thompson. 2010. The life cycle of *Tityus* (*Atreus*) *neblina* Lourenço, 2008 (Scorpiones, Buthidae) in 'Cerro de la Neblina', Brazil/Venezuela. Boletín de la Sociedad Entomológica Aragonesa 47:293–298.

Lourenço, W.R. & E. Ythier. 2007. Confirmation of reproduction by parthenogenesis in *Hottentotta hottentotta* (Fabricius) (Scorpiones, Buthidae). Acta Biológica Paranaense, Curitiba 36:213–217.

Lourenço, W.R., E. Ythier & J.L. Cloudsley-Thompson. 2007. Parthenogenesis in *Hottentotta caboverdensis* Lourenço & Ythier, 2006 (Scorpiones, Buthidae) from the Cape Verde islands. Boletín de la Sociedad Entomológica Aragonesa 41:193–196.

Matthiesen, F.A. 1962. Parthenogenesis in scorpions. Evolution 16:255–256.

Nedvéd, O., S. Pekár, P. Bezdécka, E. Líznarová, M. Řezác, M. Schmitt et al. 2011. Ecology of Arachnida alien to Europe. BioControl 56:539–550.

Oliver, J.H. Jr. 1971. Parthenogenesis in mites and ticks (Arachnida: Acari). American Zoologist 11:283–299.

Polis, G.A. & W.D. Sissom. 1990. Life history. Pp. 161–223. In The Biology of Scorpions. (G. A. Polis, ed.). Stanford University Press, Stanford, California.

Prendini, L. 2004. Systematics of the genus *Pseudolychas* Kraepelin (Scorpiones: Buthidae). Annals of the Entomological Society of America 97:37–63.

Ross, L.K. 2010. Confirmation of parthenogenesis in the medically significant, synanthropic scorpion *Tityus stigmurus* (Thorell, 1876) (Scorpiones: Buthidae). Revista Ibérica de Aracnología 18:115–121.

Sabelis, M.W. 1985. Reproduction. Pp 73–81. In *Spider Mites: Their Biology, Natural Enemies and Control.* Volume 1B. (W. Helle & M.W. Sabelis, eds.). Elsevier Science Publisher, Amsterdam.

Seiter, M. 2012. Developmental stages and reproductive biology in *Tityus confluens* Borelli, 1899 and *Tityus ocelote* (Francke & Stockwell, 1987) (Scorpiones, Buthidae). Revista Ibérica de Aracnologia 21:113–118.

Seiter, M. & J. Wolff. 2014. Description of *Sarax buxtoni* (Gravely, 1915) (Arachnida: Amblypygi: Charinidae) and a new case of parthenogenesis in Amblypygi from Singapore. Journal of Arachnology 42:233–239.

Toscano-Gadea, C.A. 2001. Is *Tityus uruguayensis* Borelli, 1901 really parthenogenetic? Pp. 359–364. *In* Scorpions 2001. In Memoriam Gary A.Polis. (V. Fet & P.A. Selden, eds.). Burnham Beeches, Bucks.

Toscano-Gadea, C.A. 2004. Confirmation of parthenogenesis in *Tityus trivittatus* Kraepelin 1898 (Scorpiones, Buthidae). Journal of Arachnology 32:866–869.

Tsurusaki, N. 1986. Parthenogenesis and geographic variation of sex ratio in two species of *Leiobunum* (Arachnida, Opiliones). Zoological Science 3:517–532.

Vandel, A. 1928. La parthénogenèse géographique: Contribution à l'étude biologique et cytologique de la parthénogenèse naturelle. Bulletin de Biologie France Belgique 62:164–281.

Weygoldt, P. 2005. Biogeography, systematic position, and reproduction of *Charinus ioanniticus* (Kritscher 1959), with the description of a new species from Pakistan (Chelicerata, Amblypygi, Charinidae). Senckenbergiana Biologica 85:43–56.

Weygoldt, P. 2007. Parthenogenesis and reproduction in *Charinus ioanniticus* (Kritscher, 1959) (Chelicerata, Amblypygi, Charinidae). Bulletin of the British Arachnological Society 14:81–84.

White, M.J.D. 1978. Modes of Speciation. W.H. Freeman, San Francisco, California.

Williams, G.C.D. 1975. Sex and Evolution. Princeton University Press, Princeton, New Jersey.

Yamazaki, K. & T. Makioka. 2001. Ovarian structural features reflecting repeated pregnancies and parturitions in a viviparous scorpion, *Liocheles australasiae*. Zoological Science 18:277–282.

Zawierucha, K., P. Szymkowiak, M. Dabert & M. Harvey. 2013. First record of the schizomid *Stenochrus portoricensis* (Schizomida: Hubbardiidae) in Poland, with DNA barcode data. Turkish Journal of Zoology 37:357–361.

Zolessi, L.C. de. 1985. La partenogénesis en le escorpión amarillo *Tityus uruguayensis* (Borelli, 1990) (Scorpionida: Buthidae). Revista de la Facultad de Humanidades y Ciencias. Tercera Época. Serv. Ciencias Biológicas 1:25–32.

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